Application of artificial neural networks to the development of improved multi-sensor retrievals of near-surface air temperature and humidity over ocean

J. Brent Roberts[1], Franklin R. Robertson[1], Carol Anne Clayson*

[1] NASA/MSFC, Earth Science Office

* Woods Hole Oceanographic Institution

Outline

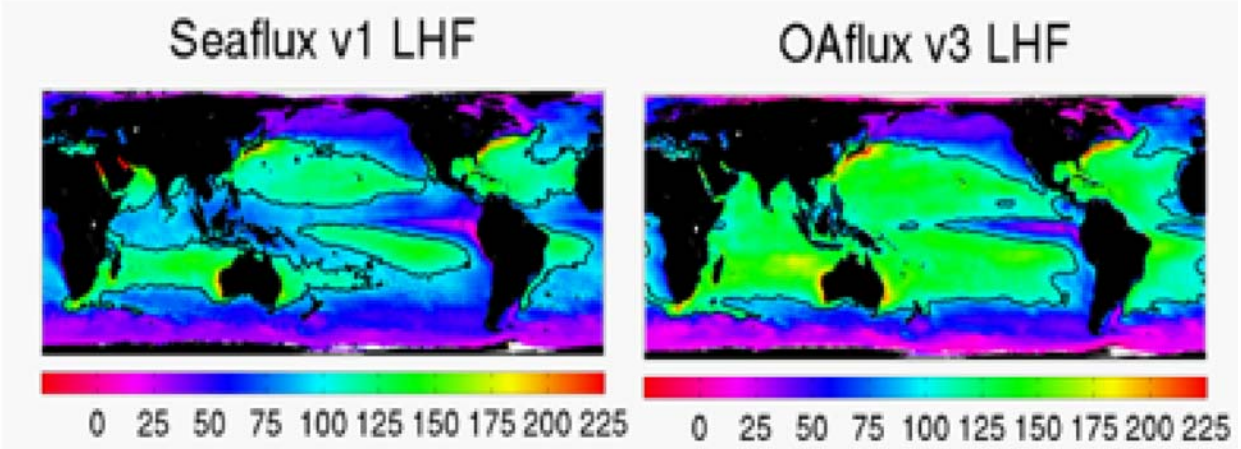
- Background
- Approach
- Results
- Conclusions and Future Work

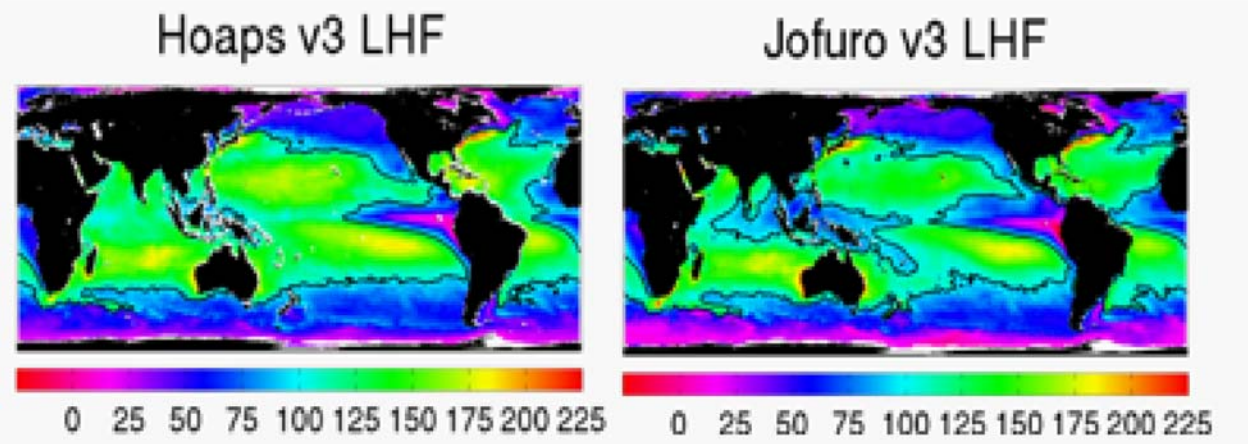
Motivation for Retrieving Surface Parameters

- Estimating the surface heat fluxes from satellite requires:
  - Sea surface temp (SST)
  - Specific humidity (Qa)
  - Air temperature (Ta)
  - Wind speed (Wspd)

- Current estimates show systematic differences of 25-50Wm^{-2}

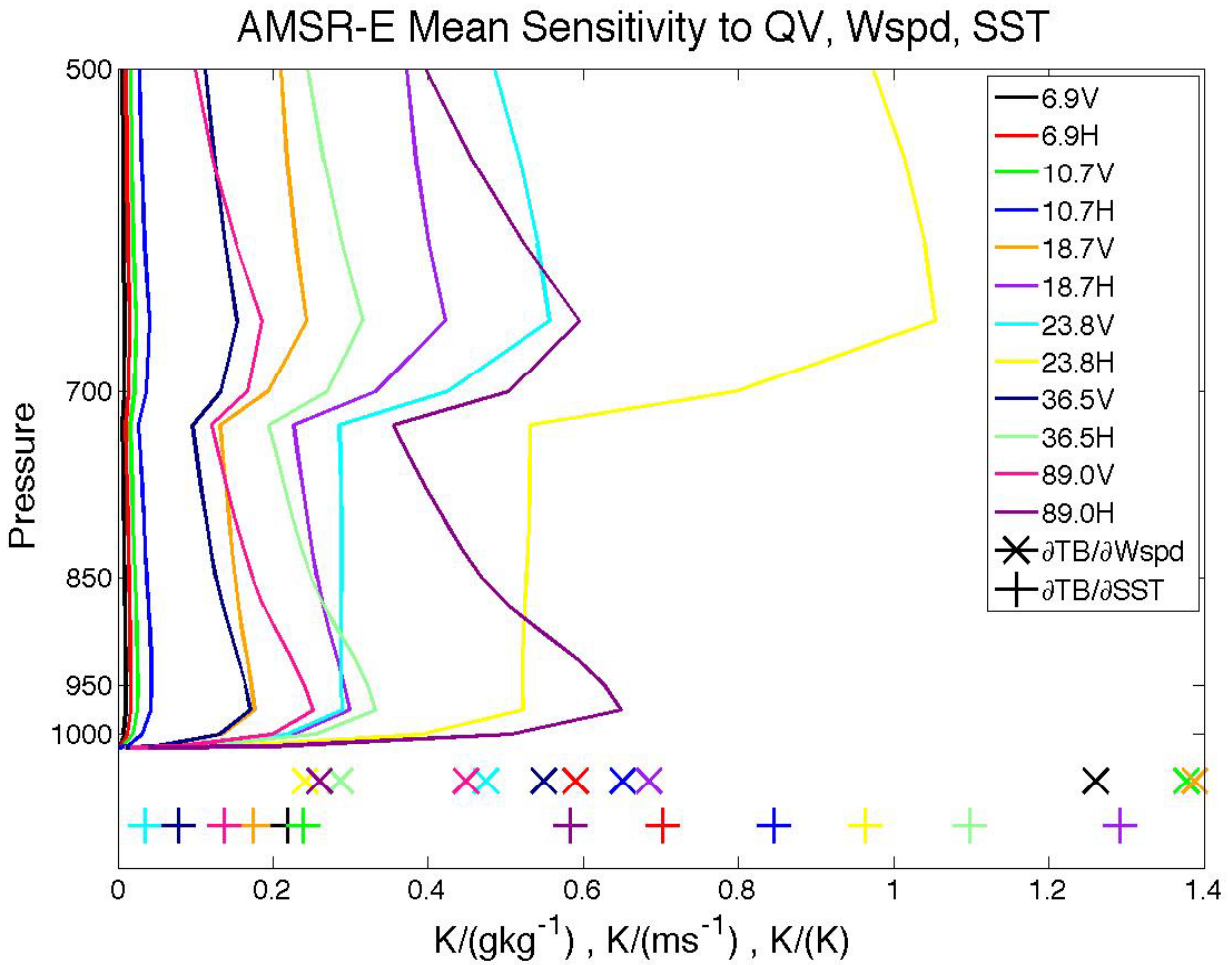
- Qa & Ta differences are a major driver of the differences between these products.





Large-scale patterns are similar but amplitudes can be very different.

Retrievals of near-surface parameters from microwave brightness temperatures

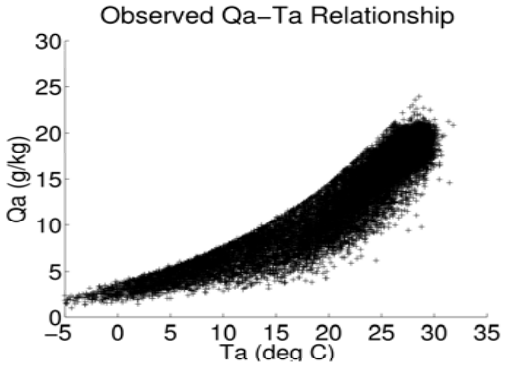


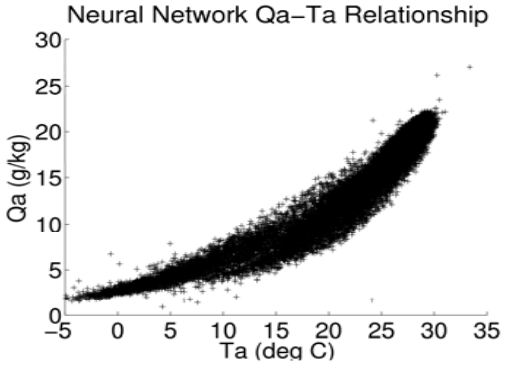
Based on simulations from CRTM Forward and Jacobian model.

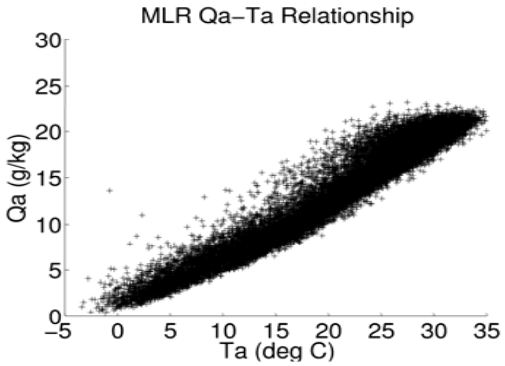
- Observations at microwave frequencies show dependencies on:
  - Water Vapor (QV)
  - Surface wind speed
  - Sea Surface Temperature
- This sensitivity is state dependent
  - Presence of clouds
- Sensitivity to surface layer (i.e. within 10m) is low

Sources of information in successful retrievals of near-surface temperature and humidity

- There is a strong connection between the near surface air-temperature and humidity.
  - Clausius-Clapeyron
- The sea surface temperature and air temperature are typically strongly correlated
  - Narrow distribution of (SST-TA)
- Studies have shown total columnar water vapor (precipitable water) and surface air temperature to be highly correlated (Liu, 1988).
- Nonlinearity arises:
  - Dependence on atmospheric state
  - Dependence on surface conditions
  - Inherent relationships between moisture and temperature.







From Roberts et al. (2010)

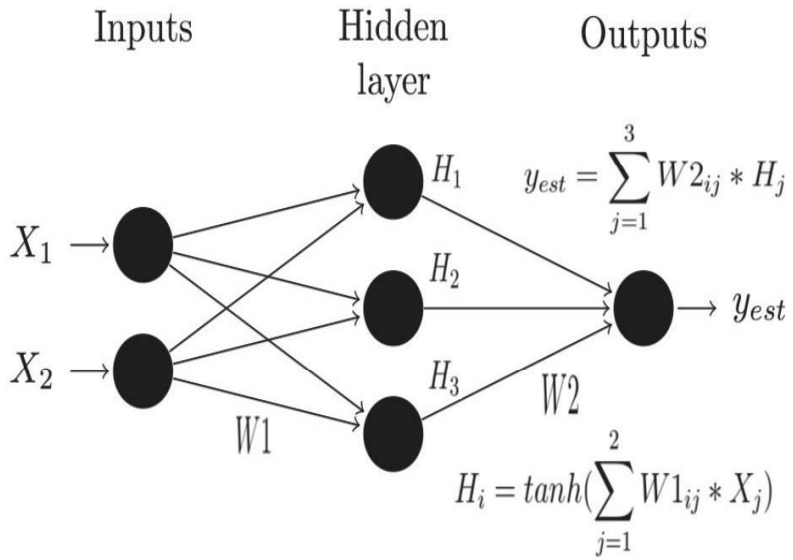
Inverse retrieval approach

$$TB = F(X) \qquad X = F^{-1}(TB)$$

GOAL: FIND $F^{-1}()$

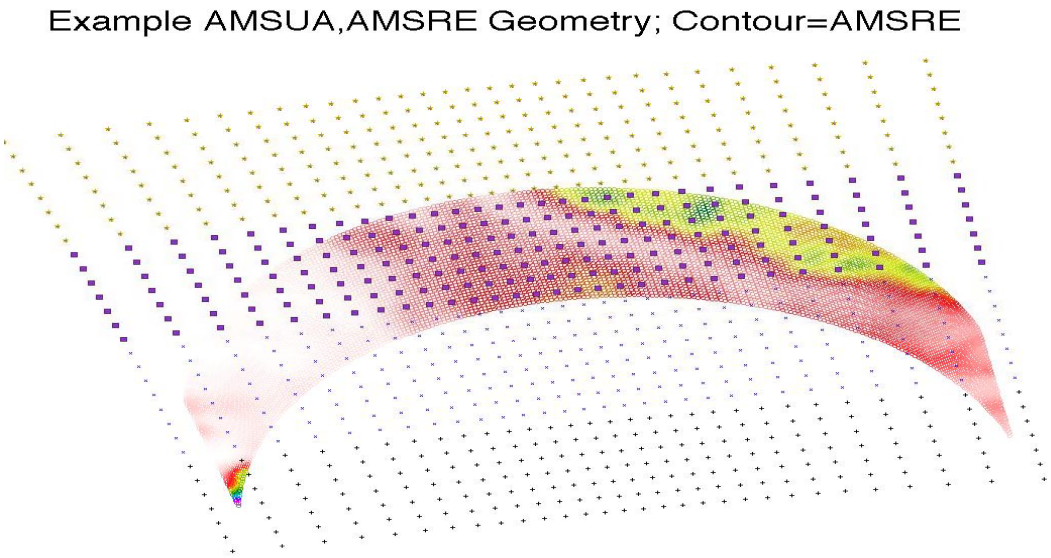
LINEAR → NON-LINEAR

- Stepwise linear regression (Jackson et al.,2006)



- Neural Network (Jones et al., 1999)
- Genetic Algorithms (Singh et al., 2006)
- Neural Network with first guess (Roberts et al., 2010)

Data Fusion: Merging AMSR-E and AMSU-A



AMSR-E and AMSU-A sensors on AQUA have co-located footprints with minimal time between samples.

- Co-located measurements between AMSR-E and AMSU-A are available from mid-2002.

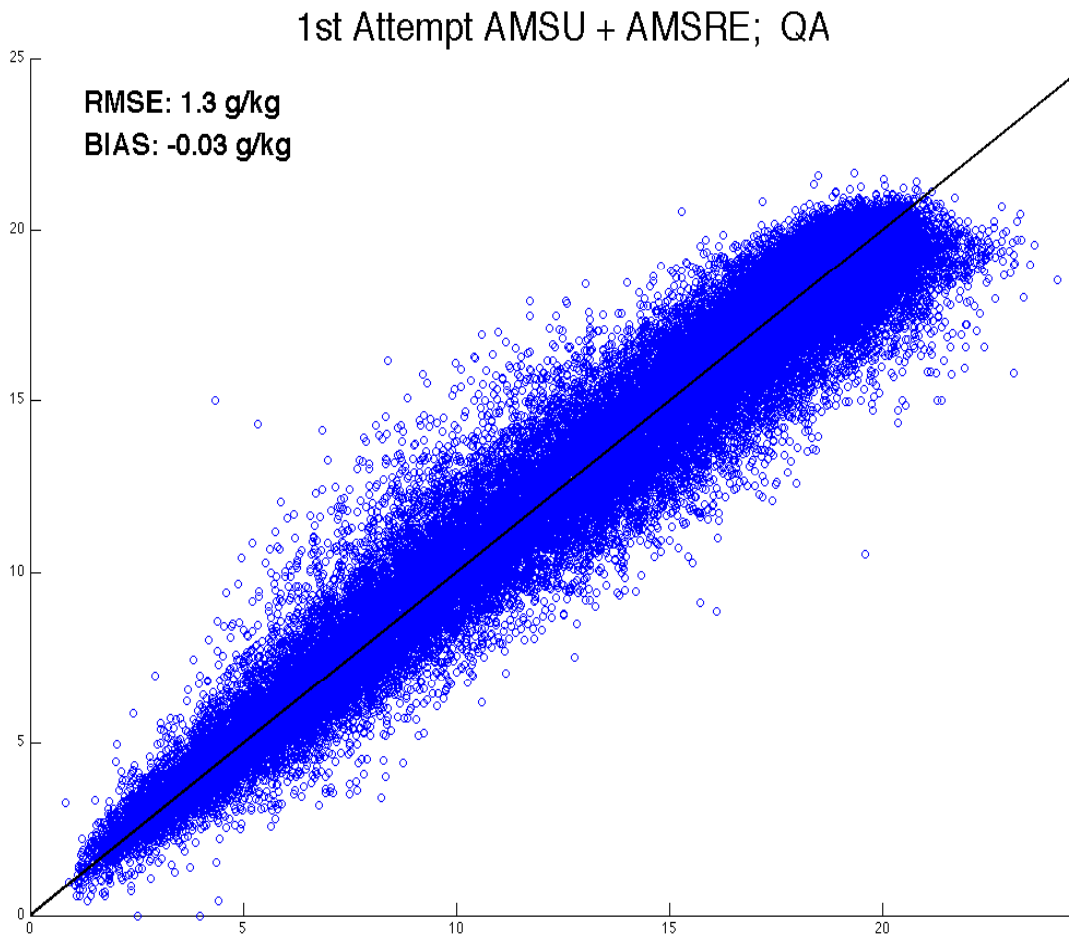
<u>Training dataset</u>

- Direct *in situ* measurements are co-located with satellite-observations.
- CRTM-based simulations can be used to supplement the *in situ* dataset.

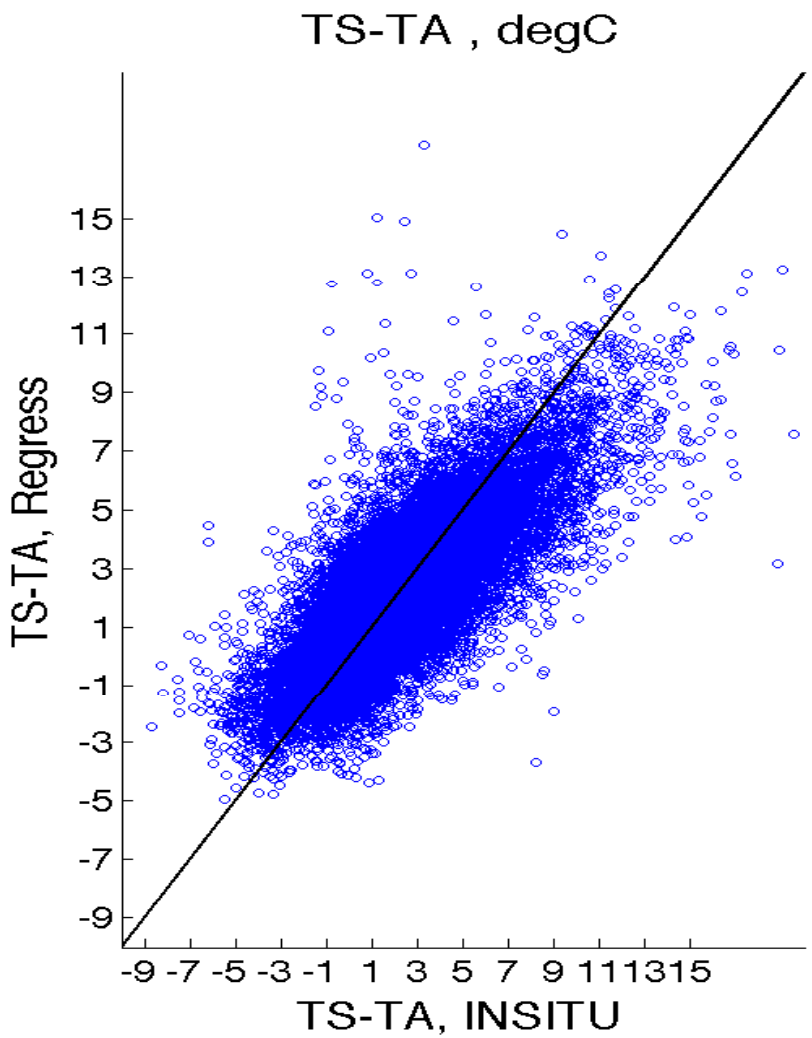
Improved Surface Humidity Retrieval

AQUA Advantage

- AMSU-A contains channels sensitive to lower troposphere temperature
- AMSR-E contains channels sensitive to PW, CLW, and SST
- Results in improved surface humidity retrievals.



Improved Surface Temperature Retrieval



- Overall improvements are found for near-surface temperature
- The near-surface stability is also better represented.
- Improved by taking information directly related to the surface temperature and temperatures in the lower troposphere.

Conclusions

- A statistical retrieval methodology for surface parameters is improved using a nonlinear approach
  - Due to nonlinear nature of the problem
- Retrieval of the near-surface parameters is improved through use of multiple sensors
  - Additional information is available for inversion
- It is important to include a synthetic component of the training dataset; choices arises regarding sampling
- Future work : add *a priori* information to help regularize the network (i.e. a Bayesian approach).

References

- Jackson, D. L., G. A. Wick, and J. J. Bates (2006), Near-surface retrieval of air temperature and specific humidity using multisensor microwave satellite observations, *J. Geophys. Res., 111*(D101306), doi:10.1029/2005JD006431.

- Jones, C., P. Peterson, and C. Gautier (1999), A new method for deriving ocean surface specific humidity and air temperature: An artificial neural network approach, *J. Appl. Meteorol., 38*, 1229-1245.

- Liu, T. W. (1988), Moisture and latent heat flux variabilities in the tropical Pacific derived from satellite data, *J. Geophys. Res. 93*, 6749-6760.

- Roberts, J. B., C. A. Clayson, F. R. Robertson, and D. L. Jackson (2010), Predicting near-surface atmospheric variables from Special Sensor Microwave/Imager using neural networks with a first-guess approach, J. Geophys. Res., 115, D19113, doi:10.1029/2009JD013099.

- Singh, R., P. C. Joshi, C. M. Kishtawal, and P. K. Pal (2006), A new method for estimation of near surface specific humidity over global oceans. *Meteorol. Atmos. Phys., 94*, 1-10.